

SPACE SHUTTLE PAYLOAD JSC-20052 VOLUME 3

# DESIGN AND DEVELOPMENT

(NASA-TM+108761) SPACE SHUTTLE PAYLDAS DESIGN AND DEVELOPMENT. VOLUME B: FLIGHT CESIGN GUIDELINES AND REQUIPEMENTS (NASA) 47 p

N94-70367

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# FLIGHT DESIGN GUIDELINES AND REQUIREMENTS

Lyndon B. Johnson Space Center

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## DESIGN AND DEVELOPMENT



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- ▶ FLIGHT DESIGN PROCESS
  - TYPICAL MISSION OVERVIEW
  - STANDARD MISSION CRITERIA
  - TYPICAL FLIGHT PROFILE
  - FLIGHT EXPERIENCE
  - SPACECRAFT FLIGHT DESIGN REQUIREMENTS

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- FLIGHT DESIGN PROCESS
  - FLIGHT DESIGN IS THE PREPARATION OF TRAJECTORY, ATTITUDE, AND CONSUMABLES PROFILES FOR A SPECIFIC FLIGHT. THERE ARE TWO MAJOR ELEMENTS -- CONCEPTUAL FLIGHT DESIGN AND OPERATIONAL FLIGHT DESIGN
    - CONCEPTUAL FLIGHT DESIGN
      - EARLY DATA BASE FOR CUSTOMER AND FOR NATIONAL SPACE TRANSPORTATION SYSTEM OPERATIONS AND SYSTEMS ORGANIZATIONS PLANNING AND ASSESSMENT
      - BEGINS 14-1/2 MONTHS PRIOR TO FLIGHT
      - CONCEPTUAL FLIGHT PROFILE COMPLETED 12-1/2 MONTHS PRIOR TO FLIGHT
      - SUPPORTS CARGO INTEGRATION REVIEW 9 MONTHS PRIOR TO FLIGHT





## FLIGHT DESIGN PROCESS (CONT)

- OPERATIONAL FLIGHT DESIGN
  - FINAL PREFLIGHT DESIGN SUPPORTS GROUND-BASED AND FLIGHT SYSTEMS RECONFIGURATION. THIS INCLUDES DATA FOR
    - RANGE SAFETY
    - CONSUMABLES LOADING
    - FLIGHT SOFTWARE
    - SHUTTLE MISSION SIMULATOR
    - MISSION CONTROL CENTER
    - "LIGHT DATA FILE
  - BEGINS 8-1/2 MONTHS PRIOR TO FLIGHT
  - OPERATIONAL FLIGHT PROFILE COMPLETED 5 MONTHS PRIOR TO FLIGHT





FLIGHT DESIGN PROCESS (CONT)

- OPERATIONAL FLIGHT DESIGN (CONT)
  - SUPPORTS
    - FLIGHT OPERATIONS REVIEW 4 MONTHS PRIOR TO FLIGHT
    - INTEGRATED SIMULATIONS STARTING 10 WEEKS PRIOR TO FLIGHT
    - FLIGHT READINESS REVIEW 2 WEEKS PRIOR TO FLIGHT
    - FLIGHT
- EARLY CONCEPTUAL FLIGHT DESIGN AVAILABLE, IF REQUIRED, AS AN OPTIONAL SERVICE
  - ESTABLISHES MISSION FEASIBILITY
  - PROVIDES FLIGHT PROFILE DATA FOR SPACECRAFT DESIGN AND EVALUATION





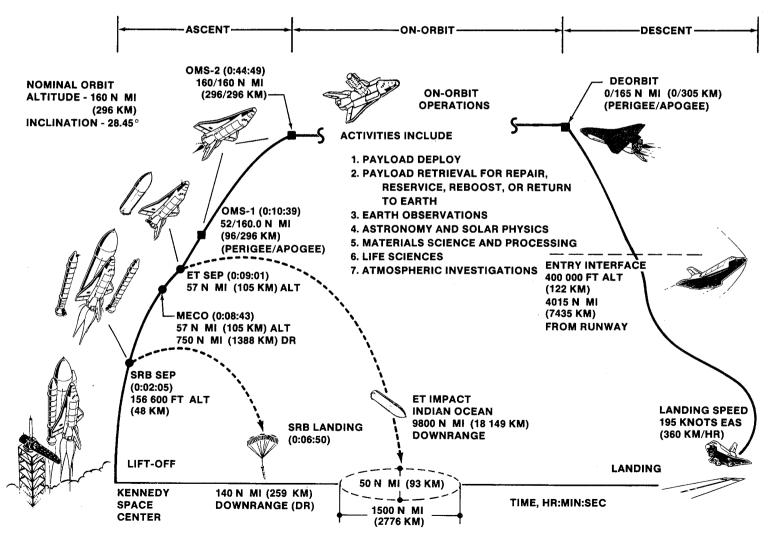
- FLIGHT DESIGN PROCESS
- TYPICAL MISSION OVERVIEW
  - STANDARD MISSION CRITERIA
  - TYPICAL FLIGHT PROFILE
  - FLIGHT EXPERIENCE
  - SPACECRAFT FLIGHT DESIGN REQUIREMENTS



#### **DESIGN AND DEVELOPMENT**

# NASA

#### TYPICAL MISSION OVERVIEW







**OUTLINE** 

- FLIGHT DESIGN PROCESS
- TYPICAL MISSION OVERVIEW
- **▶** STANDARD MISSION CRITERIA
  - TYPICAL FLIGHT PROFILE
  - FLIGHT EXPERIENCE
  - SPACECRAFT FLIGHT DESIGN REQUIREMENTS





# STANDARD MISSION CRITERIA KENNEDY SPACE CENTER LAUNCH

S-84-01434 Rev 1

#### SHARED FLIGHTS

- ORBITAL INCLINATION 28.45° AND 57.0°
- INITIAL ORBIT ALTITUDE 160 N. MI. (296 km) CIRCULAR
- LAUNCH WINDOW (FOR 28.45°)
  - TWO LAUNCH WINDOWS CENTERED NEAR NOON AND MIDNIGHT GREENWICH MEAN TIME
  - LAUNCH WINDOW DURATION 2 HRS FOR EACH WINDOW
- AT LEAST 80% OF STANDARD LAUNCH WINDOW SHOULD BE USABLE
- SPACECRAFT SHOULD BE COMPATIBLE WITH DEPLOYMENT ON 2 CONSECUTIVE ORBITAL REVOLUTIONS WITH ANOTHER OPPORTUNITY AT LEAST 12 HRS LATER

#### DEDICATED FLIGHTS

- ◆ ORBITAL INCLINATION 28.45° AND 57.0°
- INITIAL ORBIT ALTITUDE 160 N. MI. (296 km) CIRCULAR
- LAUNCH WINDOW DURATION 1 HR





# GEOSYNCHRONOUS TRANSFER ORBIT GEOMETRY FOR STANDARD SHARED FLIGHT LAUNCH WINDOW

- LAUNCH WINDOW FOR SHARED FLIGHTS COMPATIBLE WITH CLASS OF SPACECRAFT TO BE PLACED IN GEOSYNCHRONOUS ORBIT
- THESE SPACECRAFT REQUIRE THE SUN AND EARTH PARKING ORBIT NODAL CROSSINGS TO BE APPROXIMATELY ALONG TRANSFER ORBIT LINE OF APSIDES
- DUE EAST LAUNCH RESULTS IN LIFT-OFF APPROXIMATELY 90° FROM NODAL CROSSINGS; THEREFORE EARLY MORNING OR LATE EVENING LOCAL TIME LAUNCH IS REQUIRED
- FIRST NODAL CROSSING FOR LAUNCH FROM KENNEDY SPACE CENTER IS NEAR GREENWICH MERIDIAN; THEREFORE LIFT-OFF IS NEAR NOON OR MIDNIGHT GREENWICH MEAN TIME (GMT)

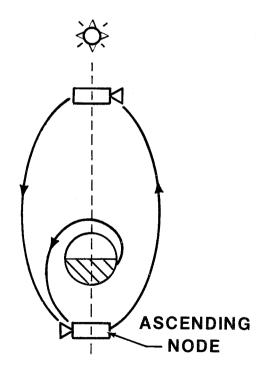


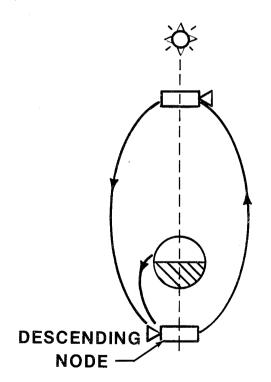


## GEOSYNCHRONOUS TRANSFER ORBIT GEOMETRY FOR STANDARD SHARED FLIGHT LAUNCH WINDOW

NOON GMT LAUNCH (MORNING EASTERN STANDARD TIME)

MIDNIGHT GMT LAUNCH
(EVENING EASTERN STANDARD TIME)









**OUTLINE** 

- FLIGHT DESIGN PROCESS
- TYPICAL MISSION OVERVIEW
- STANDARD MISSION CRITERIA
- TYPICAL FLIGHT PROFILE
  - FLIGHT EXPERIENCE
  - SPACECRAFT FLIGHT DESIGN REQUIREMENTS

#### MISSION OBJECTIVES

#### PRIMARY OBJECTIVES

- DEPLOY THREE SPACECRAFT WITH UPPER STAGES FOR EVENTUAL POSITIONING IN GEOSYNCHRONOUS ORBIT
- DEPLOY, RETRIEVE, AND RETURN TO EARTH FREE-FLYING SPACECRAFT

#### SECONDARY OBJECTIVES

- MATERIALS PROCESSING EXPERIMENTS
- STUDENT EXPERIMENTS
- GET-AWAY SPECIALS



## **DESIGN AND DEVELOPMENT**



## PROFILE OVERVIEW

LAUNCH DATE	AUGUST 9
LAUNCH TIME	12:43 GMT (8:43 EDT)
LAUNCH WINDOW	12:43 - 12:55 GMT (12 MIN)
SPACE SHUTTLE MAIN ENGINE	<b>(</b> =,
POWER LEVEL	104/104/109%
ORBITER	OV-103
NO. OF CREWMEMBERS	5
NO. OF CRYOGENIC TANK SETS	4
FLIGHT DURATION	7 DAYS + 2 DAYS EXTENSION
ORBIT INCLINATION	28.45°
ORBITAL ALTITUDE, H <sub>p</sub> /HA, N. MI. (km)	
INITIAL ORBIT	160/160 (296/296)
<ul> <li>POST-SPACECRAFT 1 SEPARATION</li> </ul>	(====,
BURN	160/166 (296/307)
<ul> <li>POST-SPACECRAFT 2 SEPARATION</li> </ul>	,
BURN	160/173 (296/320)
<ul> <li>POST-SPACECRAFT 3 SEPARATION</li> </ul>	•
BURN	160/179 (296/332)
• ORBIT ADJUST	155/160 (287/296)
	•





## PROFILE OVERVIEW (CONT)

• INJECTION OPPORTUNITIES (PRIMARY/BACKUP)

• SPACECRAFT-1 7A/23A

• SPACECRAFT-2 18A/49A

• SPACECRAFT-3 34A/49A

• LANDING SITES

• END OF MISSION

- PRIME

- ALTERNATE

• RETURN TO LAUNCH SITE

• TRANSATLANTIC ABORT

ABORT ONCE AROUND

- PRIME

- ALTERNATE

KENNEDY SPACE CENTER EDWARDS AIR FORCE BASE KENNEDY SPACE CENTER

REMILES OF AGE GENTER

DAKAR, SENEGAL

EDWARDS AIR FORCE BASE

NORTHRUP STRIP



S-84-01435

#### • FLIGHT DAY 1

MAJOR ACTIVITIES SUMMARY

- ASCENT TO ORBIT AND POSTINSERTION RECONFIGURATION
- SPACECRAFT NO. 1 DEPLOYMENT AND TRANSFER ORBIT INJECTION

#### • FLIGHT DAY 2

- SPACECRAFT NO. 2 DEPLOYMENT AND TRANSFER ORBIT INJECTION
- SPACECRAFT NO. 1 BACKUP DEPLOYMENT AND INJECTION OPPORTUNITY

#### • FLIGHT DAY 3

- SPACECRAFT NO. 3 DEPLOYMENT AND TRANSFER ORBIT INJECTION
- MATERIALS PROCESSING

#### • FLIGHT DAY 4

- SPACECRAFT NO. 2 AND 3 BACKUP DEPLOYMENT AND INJECTION OPPORTUNITY
- ORBIT ADJUST MANEUVER TO CONTROL LANDING LIGHTING AND CROSSRANGE
- FREE-FLYING DEPLOYMENT





## MAJOR ACTIVITIES SUMMARY (CONT)

- FLIGHT DAY 5
  - MATERIALS PROCESSING
  - STUDENT EXPERIMENTS
  - MANEUVER TO INITIATE RENDEZVOUS WITH FREE-FLYING SPACECRAFT
- FLIGHT DAY 6
  - FREE-FLYING SPACECRAFT RENDEZVOUS AND RETRIEVAL
  - STUDENT EXPERIMENTS
- FLIGHT DAY 7
  - CABIN STOWAGE FOR RETURN TO EARTH
- FLIGHT DAY 8
  - RETURN TO EARTH
- FLIGHT DAY 9 (IF REQUIRED)
  - FLIGHT EXTENSION DAY
- FLIGHT DAY 10 (IF REQUIRED)
  - FLIGHT EXTENSION DAY

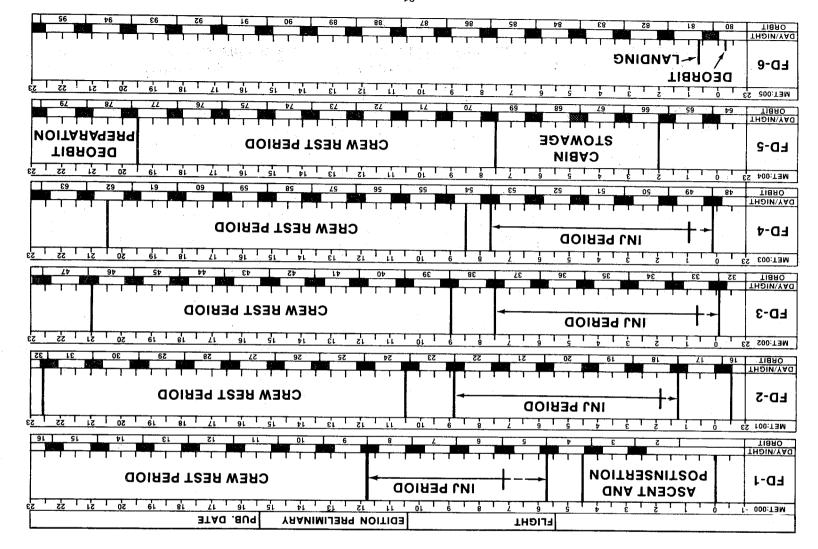




#### **DESIGN AND DEVELOPMENT**

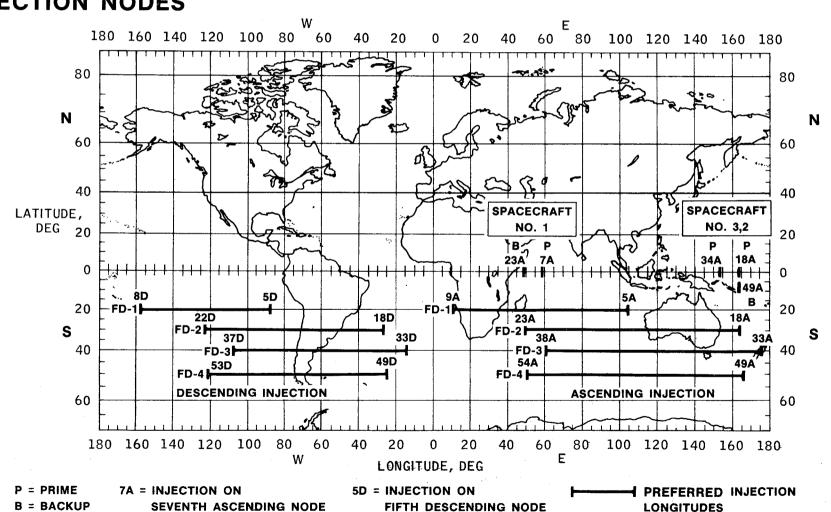
S-84-01288

## TYPICAL CREW ACTIVITY PLAN





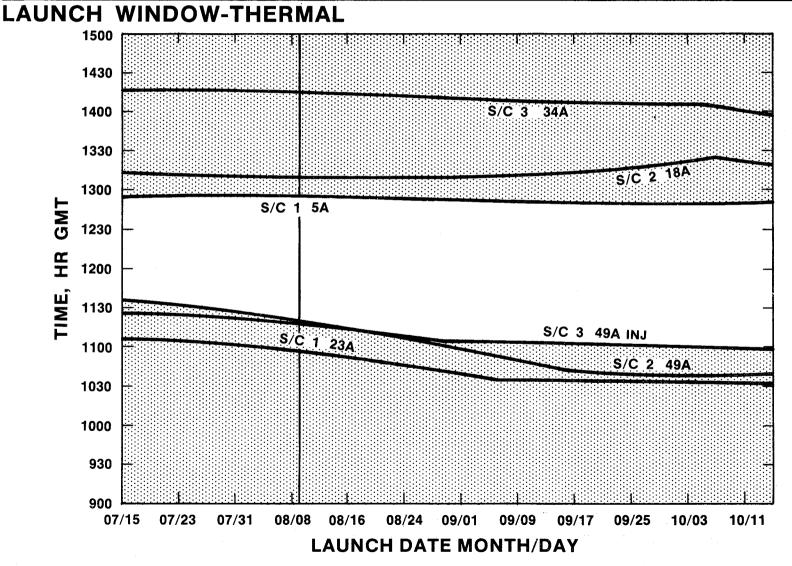
# GEOSYNCHRONOUS TRANSFER ORBIT INJECTION NODES





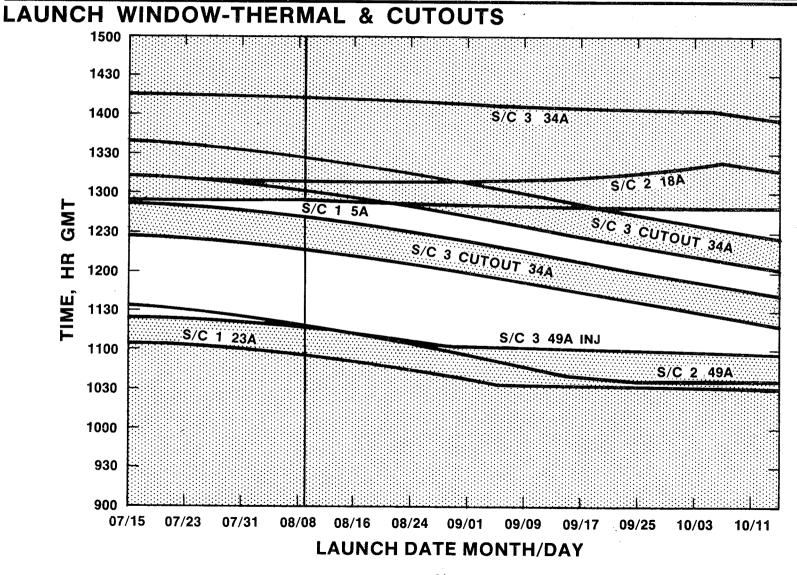
## DESIGN AND DEVELOPMENT





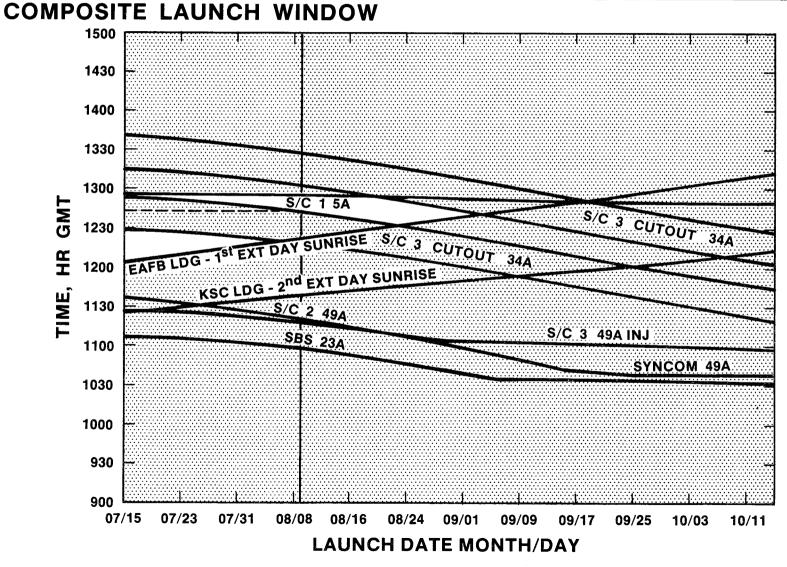


### **DESIGN AND DEVELOPMENT**





### **DESIGN AND DEVELOPMENT**







## SPACECRAFT DEPLOYMENT AND SEPARATION PROFILE

- MINIMIZES DISTURBANCES TO DEPLOYED SPACECRAFT
- PROTECTS ORBITER BY
  - MINIMIZING EROSION EFFECTS OF UPPER-STAGE EXHAUST ON ORBITER EXTERNAL SURFACES
  - ENSURING INCREASING SEPARATION DISTANCE DURING UPPER-STAGE THRUSTING
  - ENSURING ADEQUATE SEPARATION DISTANCE
    TO MINIMIZE POTENTIAL FOR DAMAGE DUE TO UPPER-STAGE
    EXPLOSIVE POTENTIAL





## SPACECRAFT DEPLOYMENT AND SEPARATION

- DEPLOYMENT
  - SPRING EJECTION SYSTEM
  - REMOTE MANIPULATOR SYSTEM
- INITIAL SEPARATION
  - IMPULSE PROVIDED BY
    - SPRING EJECTION SYSTEM
    - ORBITER REACTION CONTROL SYSTEM
  - RELATIVE SPEED
    - RECONTACT AND CREW MONITORING CONSIDERATIONS AT LEAST 0.5 FT/SEC (0.15 m/SEC)
    - SPACECRAFT WITH UPPER STAGES GREATER THAN 1.0 FT/SEC (0.3 m/SEC)
  - DIRECT VISUAL OBSERVATION UNTIL 200 FT (61 m) SEPARATION
  - SPACECRAFT ATTITUDE CONTROL THRUSTERS INHIBITED UNTIL SAFE SEPARATION DISTANCE



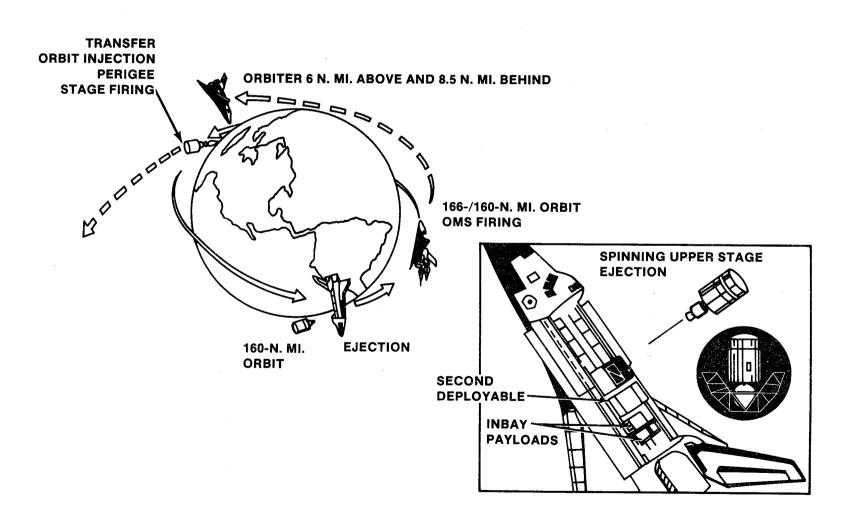


## SPACECRAFT DEPLOYMENT AND SEPARATION (CONT)

- FINAL SEPARATION MANEUVER FOR SPACECRAFT WITH UPPER STAGES
  - SEPARATION IMPULSE PROVIDED BY ORBITAL MANEUVERING SYSTEM
  - ORBITER BEHIND AND ABOVE UPPER STAGE AT STAGE IGNITION
  - 10 TO 15 N. MI. (19 TO 28 km) DISTANCE AT UPPER STAGE IGNITION

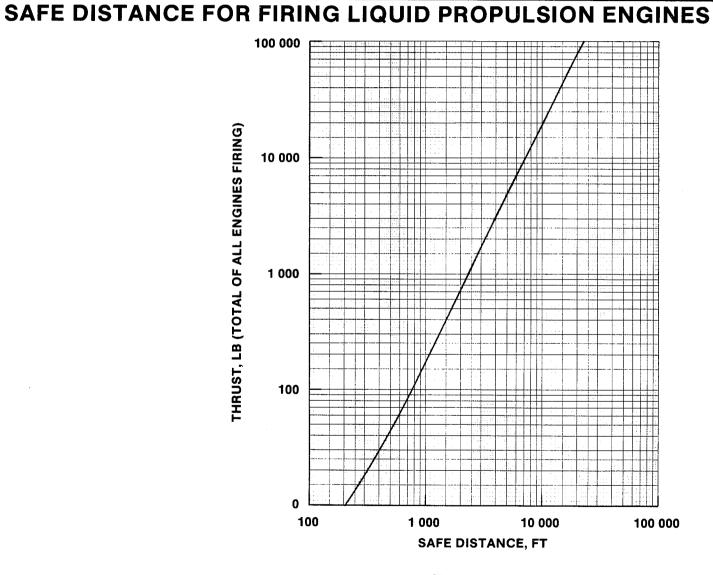


# TYPICAL SATELLITE DEPLOYMENT SEQUENCE





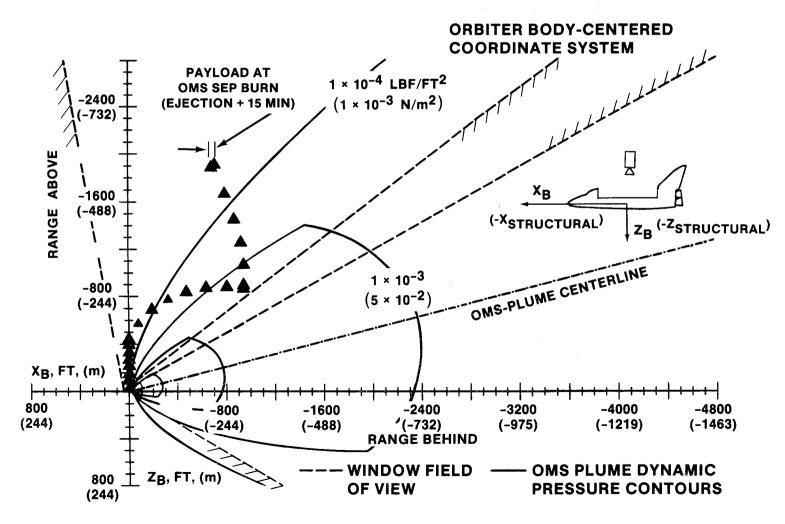
# DESIGN AND DEVELOPMENT





# DEPLOYED SPACECRAFT RELATIVE MOTION

S-84-01283 Rev 1

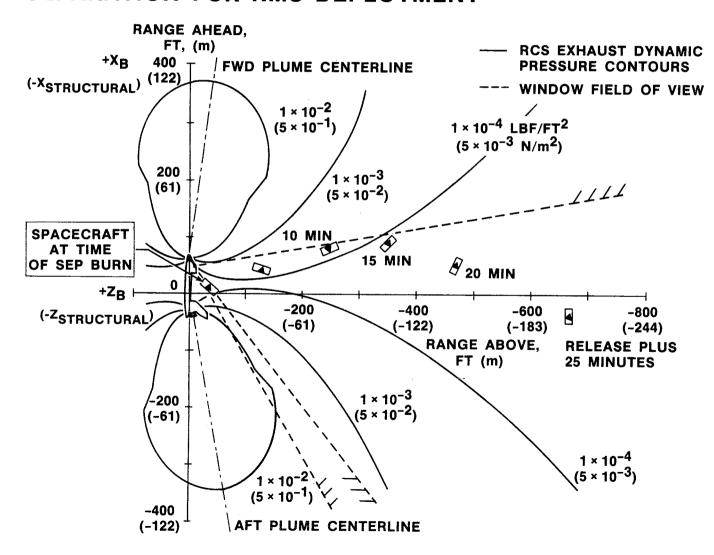




# N/S/

## INITIAL SEPARATION FOR RMS DEPLOYMENT

S-84-01284 Rev 1

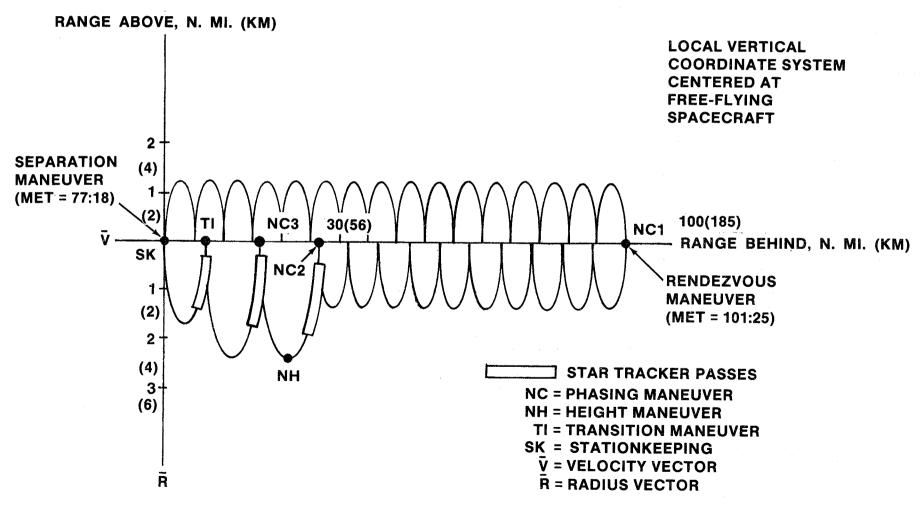






#### SPACECRAFT RENDEZVOUS PROFILE

**FAR-FIELD RENDEZVOUS PROFILE** 



**FAR-FIELD PROFILE** 



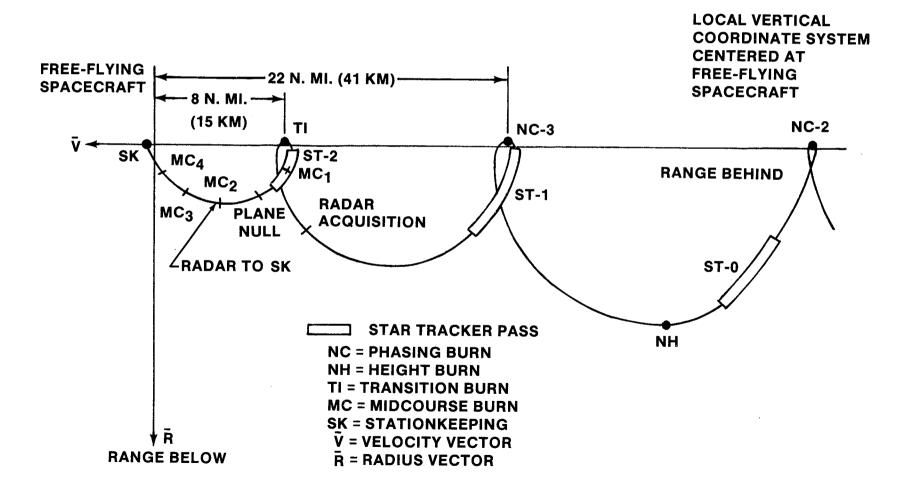
#### **DESIGN AND DEVELOPMENT**



S-84-01898

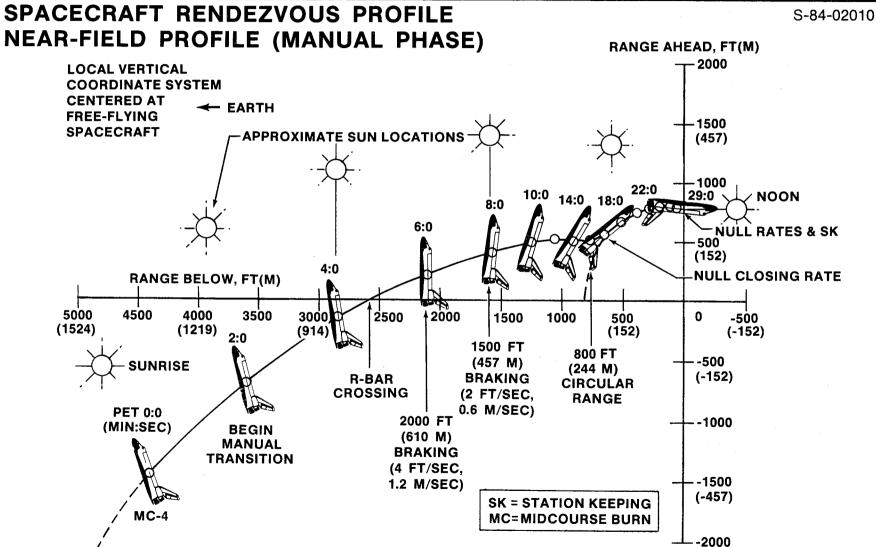
## **SPACECRAFT RENDEZVOUS PROFILE**

**DAY OF RENDEZVOUS PROFILE** 



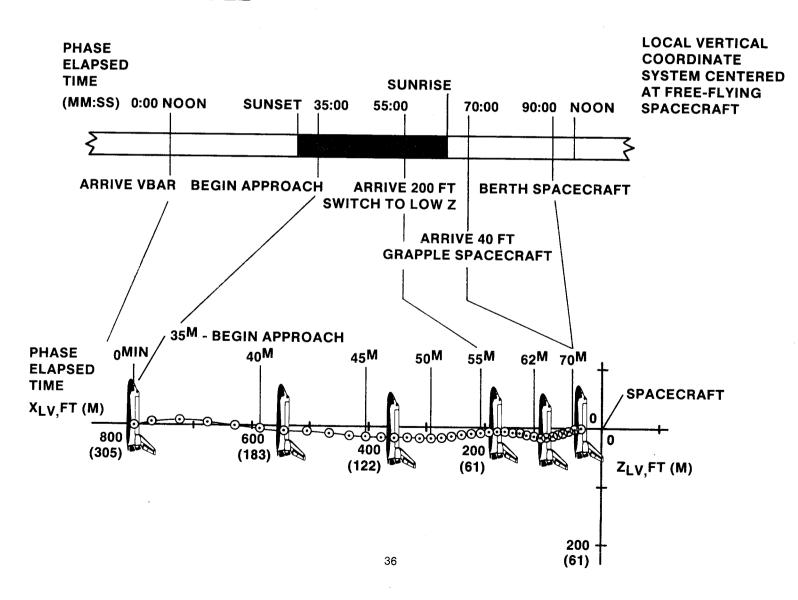








### **APPROACH TO GRAPPLE**







#### DEPLOYMENT, RENDEZVOUS, AND RETRIEVAL CONSIDERATIONS S-84-02072

- SPACECRAFT GROUND TRACKING
  - SPACECRAFT MUST BE TRACKABLE BY GROUND-BASED SYSTEMS FOR RENDEZVOUS TARGETING
- SPACECRAFT TRACKING BY ORBITER
  - CROSS-SECTION AREA GREATER THAN 1 SQUARE METER IN ALL ATTITUDES FOR ADEQUATE RENDEZVOUS RADAR TRACKING
  - GREATER THAN 3RD MAGNITUDE STAR AT RANGE OF 250 N.MI. (463 km) FOR STAR TRACKER OPERATION
  - REFLECTORS OR DISTINCTIVE MARKINGS DESIRABLE FOR VISUAL ATTITUDE DETERMINATION



NASA

### DEPLOYMENT, RENDEZVOUS, AND RETRIEVAL (CONT)

- FOR SPACECRAFT ACTIVE RENDEZVOUS, SPACECRAFT
  - SHOULD BE ABLE TO MAKE ACCURATE ORBIT CHANGES IN 24 HRS
  - SHOULD PROVIDE COMMAND LINK TO ORBITER VIA PAYLOAD INTERROGATOR
  - SHOULD BE CAPABLE OF SUSTAINING A SAFE, RETRIEVABLE CONFIGURATION FOR AT LEAST 3 HRS. THAT IS, IF SOLAR PANELS MUST BE RETRACTED OR JETTISONED, ADEQUATE BATTERY POWER MUST BE AVAILABLE
  - SHOULD HAVE ADEQUATE ATTITUDE CONTROL AUTHORITY TO FLY AT RELATIVELY LOW ALTITUDES, APPROXIMATELY 170 N.MI. (315 km) TO MAXIMIZE NSTS PERFORMANCE
- SPACECRAFT APPROACH AND GRAPPLE
  - SPACECRAFT DRAWINGS AND/OR TEST MODELS MUST BE EXACT SO THAT APPROACH AND GRAPPLE DEVICES AND CREW TRAINING CAN BE DEVELOPED
  - GRAPPLE FIXTURE ACCESSIBILITY MAY REQUIRE MULTIPLE GRAPPLE FIXTURES





DEPLOYMENT, RENDEZVOUS, AND RETRIEVAL (CONT)

- BEST SPACECRAFT ATTITUDE FOR APPROACH AND GRAPPLE IS LOCAL VERTICAL, LOCAL HORIZONTAL (ORBITAL RATE), BUT INERTIAL ATTITUDE HOLD IS ACCEPTABLE
- GRAPPLE WITH SPACECRAFT RATE UP TO 0.3°/SEC ABOUT AN AXIS NORMAL TO GRAPPLE FIXTURE SHAFT
- NSTS WILL ASSIST CUSTOMER IN DEFINING GRAPPLE FIXTURE LOCATION AND ORIENTATION BY REMOTE MANIPULATOR SYSTEM REACH AND CLEARANCE ANALYSIS

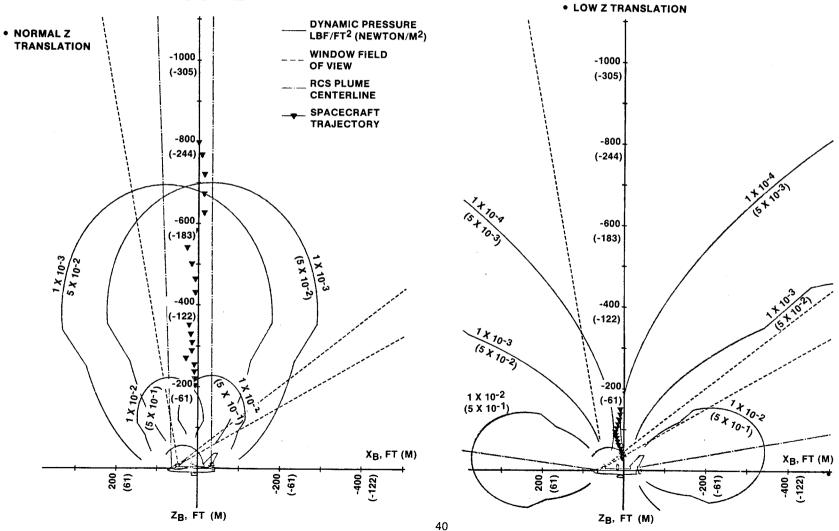


## NASA

#### **DESIGN AND DEVELOPMENT**

S-84-01900

# EXHAUST PLUME EXPOSURE DURING APPROACH DYNAMIC PRESSURE

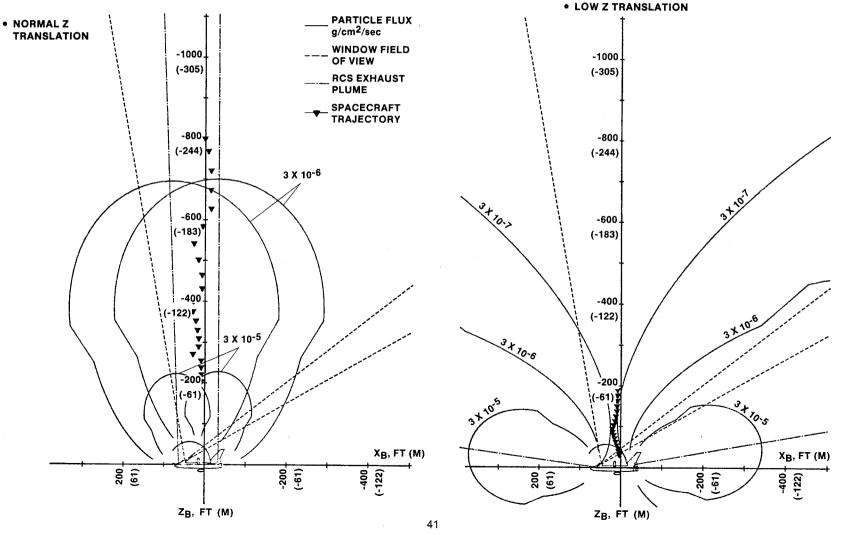




#### **DESIGN AND DEVELOPMENT**

## NASA









# TYPICAL EXHAUST PLUME IMPINGEMENT AFFECTS RETRIEVAL OPERATION

**TRANSLATION** 

**IMPULSE** 

LB-SEC

1 TO 8

(N-SEC)

(4.4 TO 35.6)

**PLUME TORQUE** 

**IMPULSE** 

FT-LB-SEC

0.3 TO 6

(N-m-SEC)

(0.4 TO 8.1)

CONTAMINATION

 $(g/cm^2)$ 

 $17 \times 10^{-8} \text{ TO } 50 \times 10^{-8}$ 





- FLIGHT DESIGN PROCESS
- TYPICAL MISSION OVERVIEW
- STANDARD MISSION CRITERIA
- TYPICAL FLIGHT PROFILE
- **▶** FLIGHT EXPERIENCE
  - SPACECRAFT FLIGHT DESIGN REQUIREMENTS





#### FLIGHT EXPERIENCE

S-84-01446 Rev 1

#### LIFT-OFF TIME

- EIGHT ON TIME ONCE THE COUNTDOWN WAS INITIATED
- FIRST NSTS FLIGHT TWO DAY DELAY, RECYCLE ON TIME
- ONE 10-MIN LATE SYSTEMS VERIFICATION
- ONE 17-MIN LATE LAUNCH SITE WEATHER
- ONE 2-MONTH DELAY MAIN ENGINE CONTROLLER PROBLEMS

#### INITIAL ORBIT ACCURACY

- ALTITUDE DISPERSION
  - APOGEE TYPICALLY LESS THAN 1.0 N. MI. (1.85 km)
  - PERIGEE TYPICALLY LESS THAN 0.5 N. MI. (0.93 km)
- ORBIT PLANE WITHIN 0.03° TO 0.04°

# ● EIGHT SPACECRAFT WITH UPPER STAGE SUCCESSFULLY DEPLOYED

- SEVEN DEPLOYED ON PRIME OPPORTUNITY WITH ONE DELAYED TWO DAYS AT CUSTOMER REQUEST
- DEPLOYED WITHIN 1 SEC OF PLANNED TIME
- DEPLOYED WITHIN 0.5° OF PLANNED ATTITUDE



# NASA

#### FLIGHT EXPERIENCE (CONT)

- FLIGHT DURATION
  - TEN FLIGHTS PLANNED DURATION OR LONGER
  - ONE EARLY TERMINATION (DURING FLIGHT TEST PROGRAM)
  - TWO FLIGHTS EXTENDED ONE DAY
    - ADDITIONAL SCIENTIFIC RETURN
    - ACCOMPLISH MISSION OBJECTIVES
  - THREE FLIGHTS EXTENDED TO AVOID UNFAVORABLE WEATHER CONDITIONS AT PRIME LANDING SITE (1 DAY, 2 ORBITS, AND 1 ORBIT)
- NAVIGATION UNCERTAINTY AT UPPER-STAGE DEPLOYMENT LESS THAN 1 N. MI. (1.85 km) DOWNTRACK
- SUCCESSFULLY DEMONSTRATED FOLLOWING CAPABILITY
  - PROXIMITY OPERATIONS WITH FREE-FLYING SPACECRAFT
  - SPACECRAFT DEPLOYMENT AND RETRIEVAL WITH REMOTE MANIPULATOR SYSTEM
  - RETRIEVAL, REPAIR, AND REDEPLOYMENT OF A DISABLED SPACECRAFT
  - ACCURATE GROUNDTRACK CONTROL
  - NIGHT LAUNCH AND LANDING OPERATIONS





- FLIGHT DESIGN PROCESS
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#### SPACECRAFT FLIGHT DESIGN REQUIREMENTS

- PHYSICAL CHARACTERISTICS
  - MASS PROPERTIES
    - CONTROL WEIGHT
    - INERTIAS
  - PHYSICAL DIMENSIONS
  - REMOTE MANIPULATOR ARM GRAPPLE FIXTURE LOCATION
- ORBIT REQUIREMENTS NOMINAL AND ACCEPTABLE TOLERANCE
  - ALTITUDE
  - INCLINATION
- LAUNCH WINDOW
  - RIGHT ASCENSION OF ASCENDING NODE FOR LAUNCH DATE AND SUBSEQUENT 60-DAY INTERVAL





#### SPACECRAFT FLIGHT DESIGN REQUIREMENTS (CONT)

S-84-01460 Rev 1

- DEPLOYMENT REQUIREMENTS
  - ACCEPTABLE LONGITUDES
  - TIMING AND POINTING
- THERMAL CONTROL REQUIREMENTS
  - ORBITER ATTITUDE CONSTRAINTS
  - COOLING REQUIREMENTS
    - COOLANT INTERFACES (CABIN AIR, WATER LOOP, FREON LOOP)
  - COOLING LOADS BY MISSION PHASE
- ELECTRICAL POWER REQUIREMENTS
  - PEAK POWER
  - TOTAL ENERGY
  - POWER PROFILE BY MISSION PHASE
- COMMUNICATIONS REQUIREMENTS
  - TIMING AND DURATION
  - COMMUNICATIONS MODES





- SPACECRAFT FLIGHT DESIGN REQUIREMENTS (CONT)
  - **ATTITUDE AND POINTING REQUIREMENTS**
  - DEPLOYMENT AND SEPARATION REQUIREMENTS
    - DEPLOYMENT MECHANISM
    - VELOCITY INCREMENT
    - UPPER-STAGE IGNITION TIME AND ATTITUDE